Abstract: The presence of an Intravascular Foreign Body (IFB) represents a well-known risk of serious complications. In the past, surgical removal of IFB has been the only option available. However nowadays percutaneous approach in retrieval an IFB is widely accepted as first line technique. In literature are generally described many case reports performed by various operators, with different experience, techniques and materials. In this paper we illustrated the main materials and techniques applied for percutaneous retrieval of IFB, in order to simplify the different possibilities adaptable to different clinical situations.
<table>
<thead>
<tr>
<th>Question</th>
<th>Response</th>
</tr>
</thead>
<tbody>
<tr>
<td>Please confirm that the manuscript is not under consideration for publication elsewhere in a similar form, in any language, except in abstract form</td>
<td>I confirm that the manuscript is not under consideration for publication elsewhere in a similar form, in any language, except in abstract form</td>
</tr>
<tr>
<td>Has your study received financial support? Please disclose any financial support (grants and funds) received in support of the study.</td>
<td>No grants or funding have been received for this study</td>
</tr>
<tr>
<td>Financial/proprietary interest</td>
<td>Do you or your co-authors have any financial interest related to this study? Financial interest is defined as any financial gain or expectancy of financial gain brought to the Author or to his/her family; ownership of stock options in a manufacturing company; involvement in any for-profit or not-for-profit corporation where the Author or his/her family is a director or recipient of a grant, including consultant and travel aid.</td>
</tr>
<tr>
<td>Does your manuscript include figures, tables or text published elsewhere?</td>
<td>This manuscript is entirely original</td>
</tr>
<tr>
<td>Meeting presentation. Have the data been presented at a scientific meeting?</td>
<td>This article was not previously presented at a meeting</td>
</tr>
<tr>
<td>Please state if any of the authors are members of the following affiliated societies</td>
<td>NONE</td>
</tr>
<tr>
<td>Response to Reviewers:</td>
<td>Dear reviewers, as requested the minor revisions were carried out. We hope that the amended article may be suitable for publication. Best regards, Umberto Rossi</td>
</tr>
</tbody>
</table>
This document is signed by the corresponding author on behalf of all co-authors.

The author who signs this agreement has full right, power and authority to enter into this agreement on behalf of all co-authors. Listed Authors have agreed to be listed authors and have granted the signing author authority to enter into this agreement on their behalf.

<table>
<thead>
<tr>
<th>Corresponding Author</th>
<th>Umberto G. Rossi</th>
</tr>
</thead>
<tbody>
<tr>
<td>Date</td>
<td>26-03-2018</td>
</tr>
</tbody>
</table>

| Manuscript Title | Materials and Techniques for Percutaneous Retrieval of Intravascular Foreign Body. |

Transfer of copyright

Authors agree to transfer and assign exclusively to Wichtig Publishing SrL (Publisher) all Author’s right, title and interest in the Article, including, without limitation, the copyright therein. These rights include mechanical, electronic and visual reproduction; electronic storage and retrieval; and all other forms of electronic publication or any other types of publication including all subsidiary rights.

In return for the above rights, the authors retain the following rights:

Provided the source is fully quoted at all times, authors are hereby granted the right to:

a) Reproduce the manuscript in whole or in part in any printed book or thesis of which they are the author(s).
b) They and any academic institution where they work at the time may reproduce the manuscript in a reasonable number of copies for the purpose of course teaching. This does not apply if a commercial charge is made for the training course.
c) To post a copy of the manuscript as accepted for publication after peer review (in word or text format) on the authors’ website provided that they also link to the article on the journal’s web site.
d) To reuse figures or tables created by them and contained in the manuscript in other works created by them.

Compliance with funding bodies

Authors retain the right to provide a copy of the final peer-reviewed manuscript to the NIH or other funding agencies upon acceptance for publication, in accordance to the organization’s policy. It is the authors’ responsibility to take the necessary actions to achieve compliance.

Authorship responsibility

Each author certifies they have participated sufficiently in the preparation of this work to take public responsibility for it.

Each author warrants and certifies that:

a) This work does not violate any trademark registrations nor the right of privacy of any person, contains libelous, obscene, or other unlawful matter, and does not infringe upon the statutory or common law copyright or any other right of any person or party.
b) Each author warrants that this manuscript is original, has not been published elsewhere in any form, electronic or in print—in part, or its entirety—and is not being considered for publication elsewhere while under consideration for this publication.
c) The authors certify also that the data on which the manuscript is based will be supplied upon request of the reviewers if required.
d) Each author further warrants that he or she has obtained, prior to submission, written releases from patients whose names or photographs are submitted as part of the work and that they will be supplied upon request.
e) Nothing in the contribution is obscene, defamatory, libelous, violates any right of privacy or infringes any intellectual property rights (including copyright, patent or trademark) or any other human, personal or other rights of any person or entity or is otherwise unlawful.
f) Nothing in the contribution infringes any duty of confidentiality which any of the authors may owe to anyone else or violates any contract, express or implied, of any of the authors, and all of the institutions in which work recorded in the contribution was carried out have authorised its publication.
g) If the contribution includes materials of others excerpts (text, figures, tables, or illustrations), the authors have obtained written permission from the copyright holder prior to submission to enable them to grant the rights contained herein. Copies of all such permissions are attached to the submission and credit to the original publication has been properly acknowledged in the manuscript.
h) Authors hereby consent to the inclusion of electronic links from the contribution to third-party material wherever it may be located.

If the manuscript will for any reason not be published, the Publisher will give prompt notice to the Author and this agreement shall terminate. Neither the author(s) nor the publisher shall be under any further liability or obligation.

Signed for and on behalf of the authors:

Umberto G. Rossi
REVIEW

Materials and Techniques for Percutaneous Retrieval of Intravascular Foreign Bodies

Umberto G. Rossi, MD, EBIR\(^1\); Gian Andrea Rollandi, MD\(^2\); Anna Maria Ierardi, MD\(^3\); Alessandro Valdata, MD\(^4\); Francesco Pinna, MD\(^1\); Lorenzo Carlo Pescatori, MD\(^4\); Maurizio Gallieni, MD, Prof\(^5\); Gianpaolo Carrafiello, MD, Prof\(^3\); and Maurizio Cariati, MD\(^6\).

\(^1\)Department of Diagnostic Imaging - Interventional Radiology Unit
Galliera Hospital
Mura delle Cappuccine, 14 - 16128 Genova, ITALY

\(^2\)Department of Diagnostic Imaging - Radiology Unit
Galliera Hospital
Mura delle Cappuccine, 14 - 16128 Genova, ITALY

\(^3\)Radiology and Interventional Radiology Unit
ASST Santi Paolo and Carlo - San Paolo Hospital
Via Pio II, 3 - 20153 Milano, ITALY

\(^4\)Postgraduation School of Radiodiagnostics, University of Milano
Piazza Edmondo Malan, 1 - 20097 San Donato Milanese, Milano, ITALY

\(^5\)Nephrology and Dialysis Unit
ASST Santi Paolo and Carlo Hospital
Via Pio II, 3 - 20153 Milano, ITALY

\(^6\)Department of Diagnostic Science - Radiology and Interventional Radiology Unit
ASST Santi Paolo and Carlo - San Carlo Borromeo Hospital
Via Pio II, 3 - 20153 Milano, ITALY

Corresponding Author:
Umberto G. Rossi, MD, EBIR.
Email: urossi76@hotmail.com - umberto.rossi@galliera.it - Phone/Fax: 0039 010 563 4154

Disclosures
Financial support and Conflict of interest: None for all the authors.

Keywords: Endovascular procedures; device retrieval, intravascular foreign body, interventional radiology, young and elderly (aging) patients.
Materials and Techniques for Percutaneous Retrieval of Intravascular Foreign Bodies

Abstract

The presence of an Intravascular Foreign Body (IFB) represents a well-known risk of serious complications. While in the past surgical removal of IFB was the most common intervention, nowadays a percutaneous approach in the retrieval of an IFB is widely accepted as the first line technique. In the literature, many case reports describe different techniques and materials. This paper summarizes and illustrates the main materials and techniques currently applied for percutaneous retrieval of IFB, providing a simplified tool with different interventional possibilities, adaptable to different clinical situations.

Introduction

In the last two decades, endovascular procedures and devices have been used for an increasing numbers of clinical problems. Consequently, case series and reports regarding intravascular foreign body (IFB) retrieval have been extensively published. The first case report was published in 1954, when an intravascular catheter was found into the right atrium at autopsy [1]. Ten years later, the first report of a successful percutaneous recover was published: a fragment of a broken guide-wire was found into the right atrium and recovered with a rigid bronchoscope forceps [2]. The most common IFBs are: broken central lines and guide-wires, angiographic catheter fragments, inferior vena cava filters, embolization coils or occluding devices, endovascular stents, cardiac valve fragments [1-9]. The majority of cases deal with vascular access in dialysis and oncology patients [10-13].

Since 1964, a variety of endovascular techniques and devices have been developed and used to approach this clinical situation, such as: loop snares, baskets, balloon catheters, grasping forceps, and tip-deflecting wires [2-7]. Nowadays, endovascular approach is widely accepted as first-line treatment for retrieving IFBs, while surgery is usually proposed as a second option [3-6]. This has
increased the indication even to more fragile patients such as in the paediatric (developing) and in geriatrics (aging) one.

Given the wide range of possible endovascular devices and IFBs, an accurate preoperative planning with Multi-Detector Computed Tomography (MD-CT) imaging is mandatory to choose the best approach [3,14].

The aim of this paper is to describe in a schematic and valuable way the main endovascular materials and techniques for IFBs retrieval, in order to provide the operator with a clear range of options that can be used in this peculiar setting.

**Imaging Study for Intravascular Foreign Body Retrieval**

A preoperative multidisciplinary team discussion with a preliminary diagnostic imaging evaluation is mandatory, in order to chose the most appropriate method and technique for each patient with IFB.

Conventional X-Ray is the first-line imaging technique, but it gives only a projective localization of the IFB (not its exact location), moreover it can be used only for radiopaque materials.

Multi-Detector Computed Tomography (MD-CT) is considered the gold-standard imaging technique in this setting, because it gives information about: IFB’s characteristics and its exact anatomical location [3,14]. Ultrasound is generally used only intra-operatively, as it is considered a mandatory tool for endovascular access [15]. Finally, high-resolution Digital Subtraction Angiography (DSA) is essential in order to perform the IFB removal with an accurate vision of all endovascular procedure phases [16].

**Materials for Intravascular Foreign Body Retrieval**

*a) Loop Snare*

In the past decades, snares were homemade, through the use of a small calibre guide-wire that was folded onto itself (thus forming a loop) and inserted into an angiographic catheter. But, in this way
the loop was rigid and gave it a slightly directional shape, as it was on the same plane as the catheter. Nowadays, modern loops have been produced with the following characteristics: a single strait guide-wire loaded into an angiographic catheter, where an a-traumatic soft metal ring is welded at its distal end [3,14].

Furthermore, snare devices can have: a range of sizes (from 2 mm to 35 mm), variable emerged angle (from 0° to 90°), and they can have from one to three loops. All these characteristics greatly facilitate manipulation of the devices aiding the IFB retrieval.

b) Angioplasty Balloon Catheters

Conventional angioplasty balloon catheters (coaxial or monorail type) are used as devices for lock and then pull (with the aim to remove) IFBs that have an inner lumen or hole [3,7]. It is important to select an appropriate size of the balloon catheter. Usually, a balloon catheter 1-2 mm oversized respect the inner-lumen or the hole of the IFB is chosen in order to have a good and permanent grip between the inflated balloon catheter and the IFB.

c) Intravascular Baskets and Filters

Baskets are well-known devices made by two nitinol wires looped together giving a basket shape. The basket device has various sizes, and the smaller one is less than 3-Fr, to allow the introduction into low profile catheters and access small-caliber vessels. Embolic protection filter devices can be used as basket to remove short and small IFB in smaller, tortuous and distal vessels [6].

d) Intravascular Grasping Forceps

Intravascular grasping forceps are devices equipped with two distal tapered metallic jaws. These two metallic jaws can be opened and closed via a manual control at the bottom of the device. This device guarantees excellent grip even in IFBs without a free edge. They are available in a range of sizes from 3-Fr to 12-Fr [3]. It should be underscored that they have to be used by experienced operators as they can cause vessel wall damage or perforation [3,4,14].

Techniques for Intravascular Foreign Body Retrieval

I) Loop Snare Proximal Grab Technique
The loop snare proximal grab technique is the usual technique used for soft cylindrical with free edge IFBs (Figure 1 A–E). The size of the loop snare has to be equal or slightly smaller than the vessel diameter and bigger than the IFB diameter. When the IFB is bent, it acquires a kinked shape. So it is imperative that the whole system is loaded into an introducer with a lumen at least twice the original diameter of the IFB.

2) Loop Snare Lateral Grasp Technique

The loop snare lateral grab technique is the classic technique used for soft cylindrical IFBs without free edge (Figure 2 A–E). The loop snare is opened distal to the IFB, then a guide-wire is passed on the other side of the IFB and through the snare loop. After having stabilized the whole system (snare loop - guide-wire - kinked IFB), retrieval is performed through a long sheath introducer (with its tip as close as possible to the IFB) with an inner lumen twice the original diameter of the IFB.

3) Loop Snare Grasp - Guide-wire Technique

The loop snare grasp - guide-wire technique is the usual technique used for not soft cylindrical IFBs, characterized by an inner lumen and a free edge (Figure 3 A–E). The double use of the loop snare and of the guide inside the lumen of the IFB guaranties an excellent stability of the system. Finally, an introducer (through the vascular access) with an inner diameter slightly above the diameter of the IFB is used for the removal.

4) Angioplasty Balloon Catheter Technique

The angioplasty balloon catheter technique is used for cylindrical IFBs, with a inner lumen and a free edge (Figure 4 A–E). This technique presents two practical advantages: first, a firm grip between the balloon and the IFB, and second a tapered new tip at the proximal end of the IFB which allows a better input into the introducer during the removal. Two principles have to be considered: the diameter of the balloon catheter must be slightly larger than the internal lumen of the foreign body, and the balloon has to be inflated at low pressure (only to guarantee a grip with the IFB).

5) Dormia Basket and Filter Technique
The Dormia basket and filter techniques are two well-known techniques used for short and not essentially cylindrical in shape IFBs (Figure 5 A-E) (Figure 6 A-E). Dormia basket is used for medium-large IFBs located in large-diameter vessels. On the other hand, the Dormia filter is used for small diameter IFBs located in peripheral vessels. When the IFB has been captured, it is necessary to use a traction force that guarantees only the grip and not the possible breaking of the IFB (especially if it has a soft nature).

6) Aspiration Catheter Technique

The aspiration catheter technique is an unconventional technique used in selected cases for small and generally cylindrical IFBs (Figure 7 A-E). This technique is based on two concepts: the IFB must be stranded in a vessel reachable by the aspirating catheter (which must have an internal lumen greater than IFB), and the use of a luer-lock syringe or a negative pressure pump to create a vacuum effect, which guarantees the aspiration of the IFB into the catheter inner lumen.

7) Retrieval Forceps Technique

The retrieval forceps technique is a not conventional technique used in selected cases for IFBs without a free edge (Figure 8 A-E). This technique is still relatively high risk for causing possible iatrogenic vessel wall damage or perforation. So, an accurate preliminary imaging evaluation of IFB (size, shape, anatomic dislocation), and the use of high-definition fluoroscopy with multiplanar images are necessary conditions for the retrieval forceps technique.

Discussion

The increasing number of endovascular procedures has also increased the possible number of complications, including the endovascular shedding of IFBs. The majority of cases described are associated with vascular access devices, given their growing frequency of placement in dialysis and oncology patients [3-5, 17]. IFBs represent a feared complication of the endovascular procedures, leading to possible severe adverse events (infections, thrombosis, ischemia, perforation, and cardiac arrhythmias) if not retrieved [1-9]. The rate of these adverse events is reported as high as 71% [5,9]. This suggests that
IFBs removal must be done as soon as possible. Given the wide range of possible IFBs, a multidisciplinary approach to manage such endovascular complication is mandatory, with an accurate clinical and imaging preoperative planning to choose the best approach and procedure [3,16-18].

Nowadays, the endovascular approach is considered the first-line method for retrieving IFBs [3-6]. It offers a high success rate with a low associated morbidity [3-9, 19]. Skills in endovascular procedures and good knowledge of materials are mandatory to approach these challenging clinical situations [3-7]. However, the endovascular approach may not be always appropriate or possible in retrieving IFBs in up to 6% of the cases. So, open surgery retrieval is still indicated in these few cases [19].

After a multidisciplinary decision of an endovascular approach, the best technique and the optimal materials to use should be considered. The above described endovascular techniques can be applied individually or in combination with each other, since every case of IFB retrieval is different from the other [19-21]. Overall, the complications rate related to endovascular percutaneous retrieval procedures for IFBs is low. The most frequently reported include: cardiac arrhythmia, vascular and cardiac perforation, artery spasms and thrombosis [3-7, 22].

In conclusion, in most cases IFBs represent a challenging clinical situation. Therefore the good knowledge of materials and techniques for IFB percutaneous removal allows to perform the procedure with higher technical and clinical success.

**Figures**

*Figure 1 A-E: Loop Snare Proximal Grab Technique.* A) Presence of intravascular foreign body (*) and angiographic catheter (arrowhead). B) A loop snare is loaded into the angiographic catheter lumen (arrowhead) that is advanced above the proximal (or lower) end of the intravascular foreign body. C) The intravascular foreign body is grasped with a pull back technique of the loop snare (arrow). D) Fastening system (arrowhead) is used on the guide-wire of the loop snare to stabilize
the whole system. E) The whole system is then retrieved (arrow) inside the introducer (arrowhead), which must have a suitable inner diameter to allow the entry of the foreign body that now has twice its original diameter as it is retrieved in a kinked fashion.

**Figure 2 A-E: Loop Snare Lateral Grasp Technique.** A) A kinked intravascular foreign body in seen in the vessel (*), so a loop snare is loaded in an angiographic catheter (arrowhead). B) The loop snare is passed over the intravascular foreign body. C) Passing through the same introducer, an angulated angiographic catheter (arrowhead) advances near the intravascular foreign body. Then a strait guide-wire is pushed over the intravascular foreign body on the other side through the loop snare. D) With a pull back technique of the guide-wire of the loop snare, the strait guide-wire is grasped, and the whole system is then stabilized by the fastening system on the guide-wire of the loop snare (arrow). E) The whole system is then retrieved (arrow) inside the introducer (arrowhead), which must have a suitable inner diameter to allow the entry of the foreign body that now has twice its original diameter as it is retrieved in a kinked fashion.

**Figure 3 A-E: Loop Snare Grasp - Guidewire Technique.** A) Presence of intravascular foreign body (*) and angiographic catheter with a loop snare loaded (arrowhead) and advanced above the proximal (or lower) end of the intravascular foreign body. B) With a pull back technique of the loop snare (arrow), the intravascular foreign body is grasped; then an angulated angiographic catheter with a strait guide-wire (arrowhead) is advanced near the proximal (or lower) end of the intravascular foreign body. C) After using a fastening system (arrow) on the guide-wire of the loop snare to stabilize the whole system, the guide-wire of the angulated angiographic catheter is advanced into the intravascular foreign lumen (arrowhead). D) The angulated angiographic catheter is removed. E) The whole system is then retrieved (arrow) inside the introducer (arrowhead), which may have an inner diameter slightly above the diameter of the foreign body.
**Figure 4 A-E: Angioplasty Balloon Catheter Technique.** A) Presence of intravascular foreign body (*) and an angulated angiographic catheter (arrowhead) that has a straight guide-wire inside. B) The guide-wire of the angulated angiographic catheter is advanced into the intravascular foreign lumen (arrowhead). C) Leaving the guide-wire in place, the angulated angiographic catheter is removed and a balloon catheter (arrowhead) is loaded over the guide-wire (the balloon catheter must have a diameter slightly above the internal lumen of the foreign body). D) The balloon catheter is advanced into the foreign body lumen and then it is inflated at low pressure. E) The whole system is then retrieved (arrow) inside the introducer (arrowhead), which may have an inner diameter slightly above the diameter of the foreign body.

**Figure 5 A-E: Dormia Basket Technique.** A) Presence of intravascular foreign body (arrow) and an angiographic catheter (arrowhead). B) A Dormia basket (arrowhead) is loaded into the angiographic catheter. C) The Dormia basket is advanced open (arrow) over the intravascular foreign body. D) With a pull back technique of the Dormia basket (arrow) the intravascular foreign body is grasped. E) After using a fastening system (arrow) on the guide-wire of the Dormia basket to stabilize it, the whole system is then retrieved (long arrow) inside the introducer (arrowhead), which may have an inner diameter slightly above the diameter of the foreign body.

**Figure 6 A-E: Filter Technique.** A) Presence of intravascular foreign body (arrow) and an angiographic catheter (arrowhead). B) An angiographic filter (arrowhead) is loaded into the angiographic catheter, which is passed over the foreign body. C) The angiographic filter is retracted (arrow), in order to capture the body. D) Fastening system (arrow) is used on the guide-wire of the filter to stabilize the whole complex. E) The whole complex is then retrieved (arrow) inside the introducer (arrowhead), which may have an inner diameter slightly above the diameter of the foreign body.

**Figure 7 A-E: Aspiration Catheter Technique.** A) Presence of foreign body (arrow) within a vessel (*), and angiographic catheter (arrowhead). B) The angiographic catheter is advanced (arrow) with its tip just at the proximal (or lower) end of the intravascular foreign body (the inner...
diameter of the angiographic catheter must be bigger than the diameter of the intravascular foreign body). C) The distal part of the angiographic catheter is connected to a syringe or aspiration system. D) Exerting negative pressure with the syringe or activating the aspiration system, the intravascular foreign body is aspirated within the angiographic catheter (arrowhead) and then removed.

**Figure 8 A-E: Retrieval Forceps Technique.** A) Presence of intravascular foreign body (arrow) and intravascular retrieval forceps (arrowhead). B) The intravascular retrieval forceps are advanced close to the intravascular foreign body and then opened (arrow). C) With gentle movements the intravascular foreign body is then grasped, through the closure of the intravascular retrieval forceps (arrow). D) The whole system is then retrieved (arrow) inside the introducer (arrowhead), which may have an inner diameter slightly above the diameter of the foreign body / intravascular retrieval forceps.

**References**


